FAUNA OF THE ACCRAIAN SERIES (DEVONIAN OF GHANA)

by

John Michael Saul

Submitted in Partial Fulfillment

of the Requirements for the

Degree of Master of Science

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June, 1960

Signature of Author . ....

Department of Geology and Geophysics, May 1960

Certified by .. ..

Thesis Supervisor

Accepted by ....

Chairman, Departmental Committee on Theses

ABSTRACT

The fauna of the Accraian Series of Ghana was studied and the following identifications were made: Prismodictya, Discinisca, Lingula, a species of terebratuloid, Leiopteria, Leptodesma?, Nuculana, Nuculites, Pleurodapis, Ptychodesma, Sphenotus, Bucanella?, Liospira?, Loxonema, Ptomatis, Tropidodiscus, Hyolithes, Tentaculites, a species of homalonotid and algal growths, plant fragments, fragments of crustaceans, an Arthrophycus-like track or trail and two unidentified ostracods. This faunal assemblage could be either Lower or Middle Devonian in age. The Accraian Series should not be correlated with any Lower or Middle Devonian strata studied to date. The results of this study are not adequate to decide if the faunal facies of the Accraian Series is more closely related to the faunal facies of beds of comparable age in North Africa, South Africa, or South America.

The homalonotid and Pleurodapis were studied in detail and are new to science.

ACKNOWLEDGMENTS

The author wishes to thank Dr. H. B. Whittington of Harvard University for his assistance and suggestions concerning the measurements and description of the Accraian trilobites.

The author thanks Dr. Robert M. Finks of Brooklyn College for the time and care that he took in identifying the Accraian sponges and for describing and discussing them in detail.

The author is very grateful to Dr. A. L. McAlester of Yale University for his interest in this paper and for his many useful suggestions and ideas concerning the Accraian pelecypods.

The author gives his especial thanks to Dr. Arthur J. Boucot of the Massachusetts Institute of Technology. Professor Boucot has been very generous in donating his time and advice for this study and without his aid the paper could not have been completed.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

Seven weeks of geological field studies were conducted in July and August, 1959, along the Atlantic Coast at Accra, Ghana, West Africa. The studies were conducted on the Accraian Series which, according to previous work (Kitson, 1928), is of Middle Devonian age.

This series is of particular interest because it is isolated from other sedimentary rocks of Devonian age; the nearest such rocks are an unstudied sequence in Guinea and the nearest Devonian strata that have been studied are in North Africa and (Bokkeveld Series) in the Union of South Africa. D. A. Bates, director of the Geological Survey of Ghana, has informed the author that the Devonian strata mapped on the _Carte Géologique Internationale de l'Afrique_ (30) in central and northern Ghana do not exist.

The Accraian Series was divided into six units: basal grit, lower sandstone, clay shale, lower interbedded clay shale and sandstone, upper sandstone, and upper interbedded clay shale and sandstone. The sandstones and the basal grit are very quartzose. A total thickness for the lower three units of the series is about 2865 feet; the thicknesses and relationships of the upper units are greatly complicated by faulting and it is not clear whether the upper sandstone is above or below the upper interbedded clay shale and sandstone. The series may be either an unrepeated sequence of sediment or a shallow basin; information from boreholes is necessary to determine which. The thicknesses determined by the author were determined by considering the series to be an unrepeated sedimentary sequence (Saul, 1960).

The geological study was followed by a paleontological study during the first five months of 1960. The results of that study are presented in this paper.

Previous paleontological studies had brought about the identification of the following fossils (11, paleontological note by Dr. A. Morley Davies):

Dipleura (*Homalonotus*) *dekayi* and one other smaller species of same genus or young of species

Nuculites (*Cleidophorus*)

Palaeoneilo

Glyptodesma

Leiopteria

Leptodesma

Lunulicardium

Conocardium

a *Hyolithes* (probably *H. actis*, Hall)[1]

a *Pleuratomaria* (?)

a *Lingula*

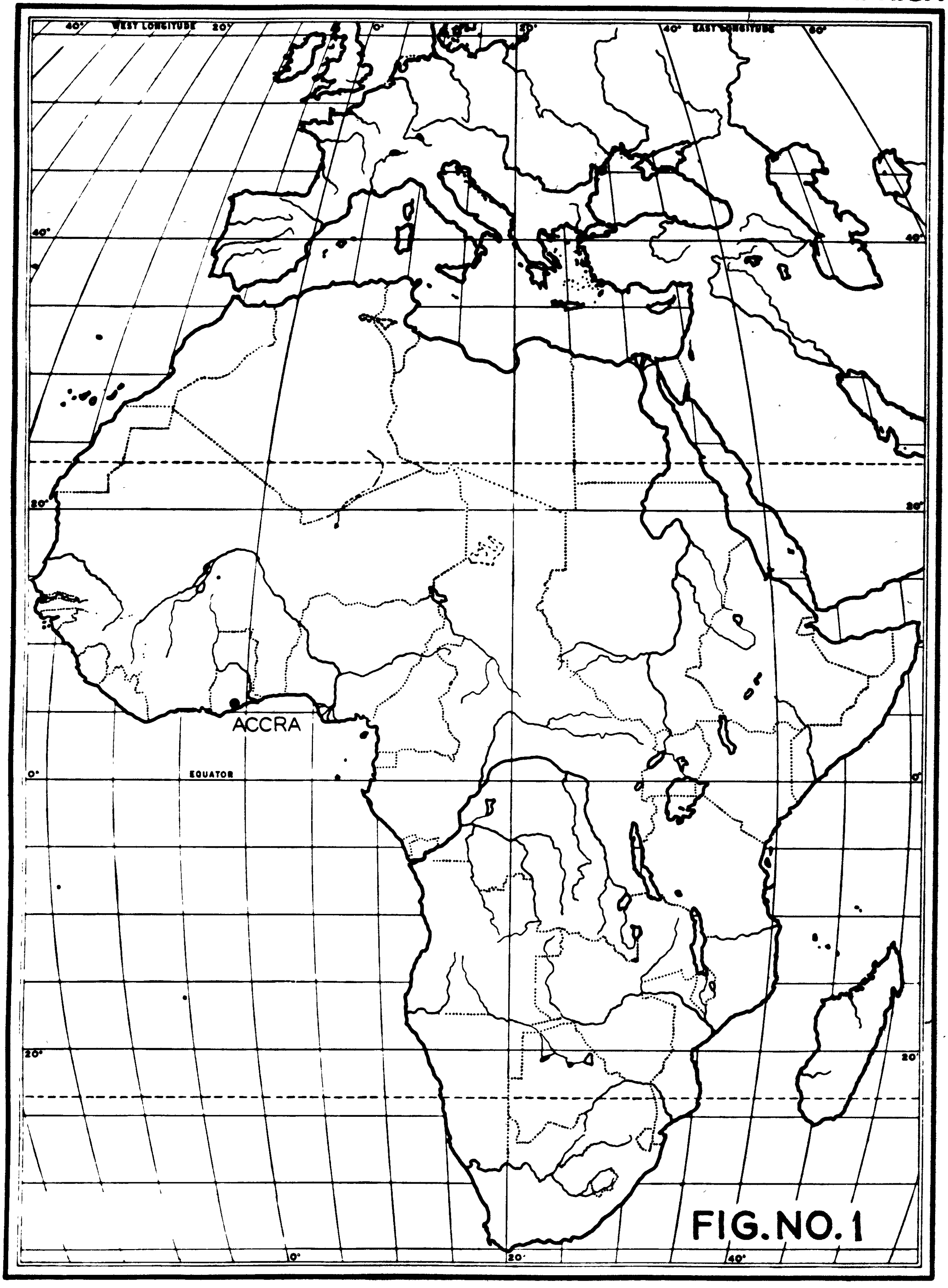
1. This is doubtless a misspelling of *H. aclis* Hall.

Plant fragments and chelae of crustaceans had also been recognized (11).

The series was regarded as Devonian and tentatively referred to the Middle Devonian Hamilton Series of New York State (11, Davies, 1922) and later to the Lower Devonian Bokkeveld of South Africa (Kitson, 1928).

A map showing the location of all fossil sites known to the author is included. These sites, with two minor exceptions, are in the clay shale unit of the series.

AFRICA


WEST LONGITUDE
EAST LONGITUDE
40°
20°
0°
40°
60°
ACCRA
EQUATOR
FIG. NO. 1

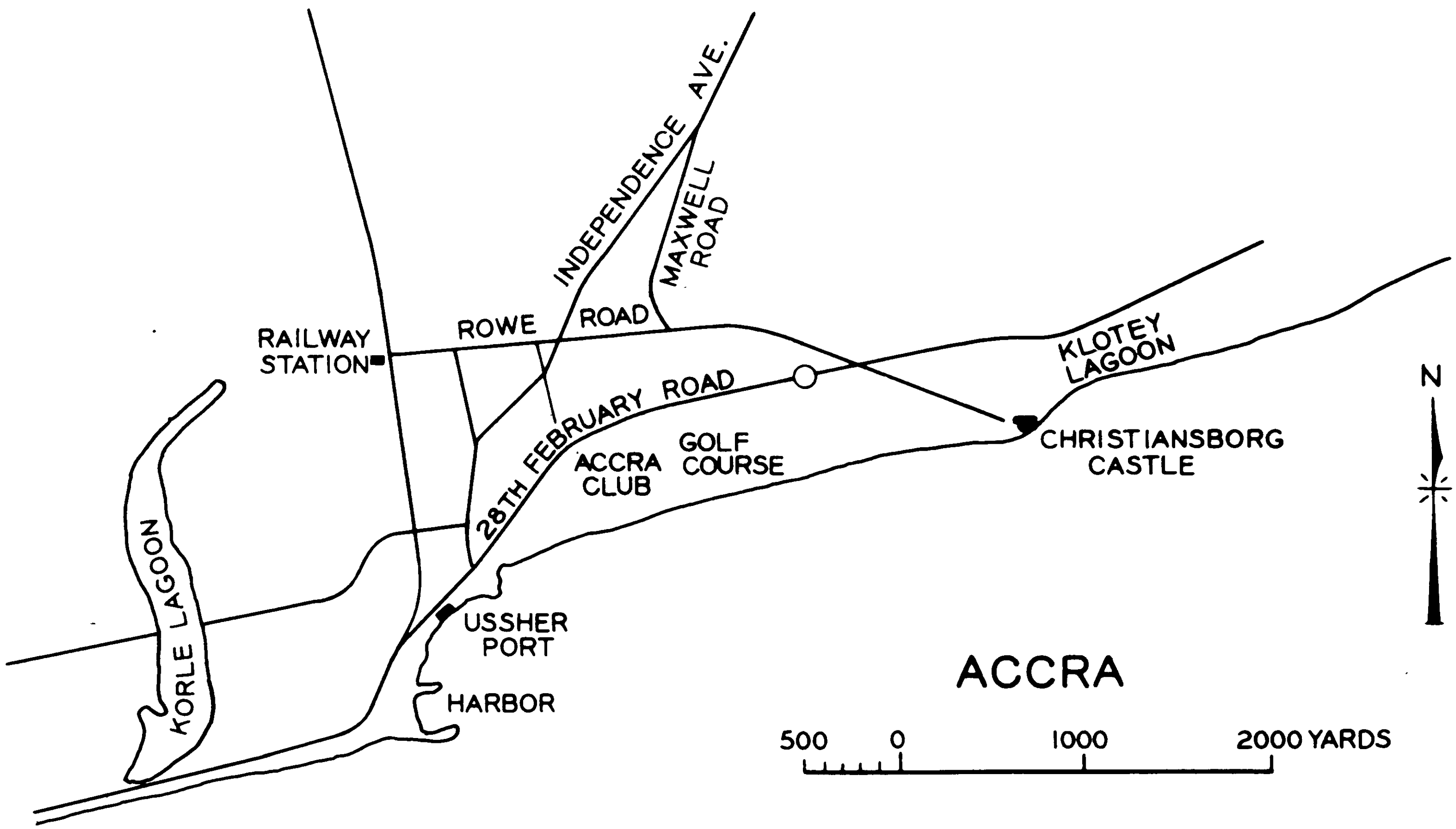

RAILWAY STATION
ROWE ROAD
INDEPENDENCE AVE.
MAXWELL ROAD
28TH FEBRUARY ROAD
ACCRA CLUB
GOLF COURSE
KLOTEY LAGOON
CHRISTIANSBORG CASTLE
KORLE LAGOON
USSHER PORT
HARBOR
N
ACCRA
500 0 1000 2000 YARDS

FIG. NO. 2

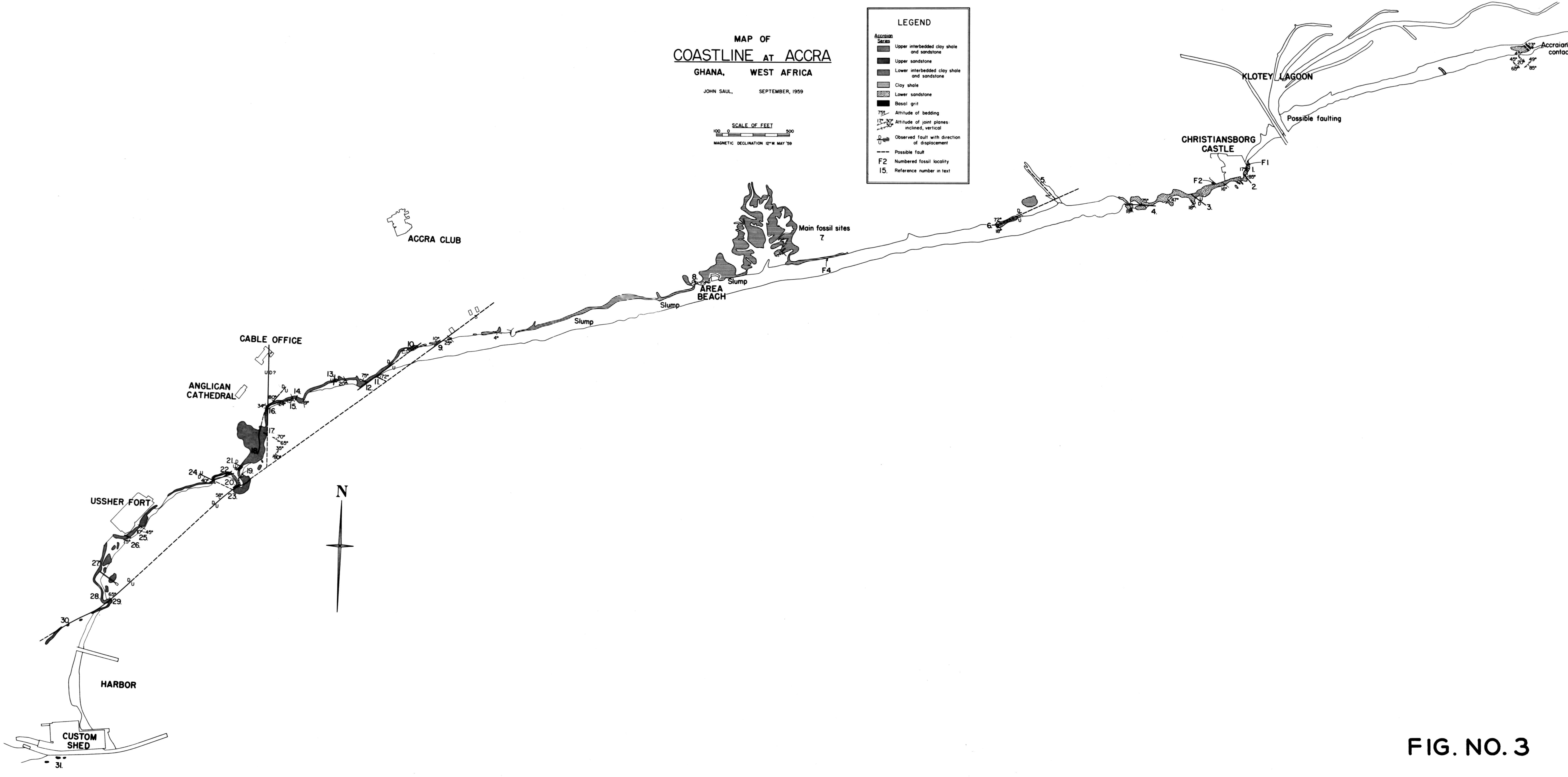

MAP OF
COASTLINE AT ACCRA
GHANA, WEST AFRICA
JOHN SAUL, SEPTEMBER, 1959
SCALE OF FEET
100 0 500
MAGNETIC DECLINATION 12°W. MAY '59
LEGEND
Accraian Series
Upper interbedded clay shale and sandstone
Upper sandstone
Lower interbedded clay shale and sandstone
Clay shale
Lower sandstone
Basal grit
Attitude of bedding
Attitude of joint planes: inclined, vertical
Observed fault with direction of displacement
Possible fault
F2 Numbered fossil locality
15. Reference number in text
KLOTEY LAGOON
Accraian – Dahomeyan contact, dips 20°S.
Possible faulting
CHRISTIANSBORG CASTLE
F1
F2
Main fossil sites
7.
F4
AREA BEACH
Slump
Slump
Slump
ACCRA CLUB
CABLE OFFICE
ANGLICAN CATHEDRAL
USSHER FORT
HARBOR
CUSTOM SHED
N

FIG. NO. 3

MAIN FOSSIL SITES

FIG. NO. 4

PALEONTOLOGY

TRILOBITA

A New Homalonotid

Elongate in shape, tapering backwards with length one and three-fourths times width. Trilobation extremely faint, especially on thorax and pygidium. Exoskeleton uniformly granulose, with usual (85% of specimens) exception of inner posterior corner of genae, also with common exception of area near genal angle.

Cephalon about twice as wide as long and semicircular to sub-trapezoidal in shape. Gonatoparian with genal angle bluntly rounded and poorly defined. Eyes small, rising high on mammiform genae. Glabella urceolate, broad and lacking lobation; pre-glabellar field absent. Anterior border furrow distinct, posterior border furrow deep and very distinct. Granules usually absent from deepest part of these furrows.

Rostral suture on upper side of cephalon. Anterior margin appearing sharply folded in anterior view due primarily to a pimple-like stout ventrally directed prominence on rostral plate. Rostral plate sub-equilateral triangular in shape. Hypostome sub-quadrate with small anterior wings, anterior margin slightly indented, and posterior margin moderately indented by circular arc. Middle body of hypostome gently convex with well marked middle furrow.

Thorax marked by broad flat axis, contains thirteen segments in adult. Pleural extremities rounded. Articulating furrow distinct,as is transverse groove which divides each axial ring into two subequal portions and continues as pleural furrow. Granulose markings sparse or absent near edges and ends of segments.

Length of pygidium slightly greater than length of cephalon. Pygidium slightly wider than long, parabolic in shape, obtusely pointed behind and turning up very slightly at posterior. Outline of axis faint, triangular in shape. One ring furrow in extreme anterior part of pygidium always very distinct and deep in adult; about six or seven others usually faintly present. About seven faint pleural furrows present. Posterior of pygidium smooth.

ONTOGENY

All but four specimens collected (169, 174, 177, 178) were in the holaspid period. Large and small holaspid specimens appear to vary in overall size and size of granules only. One meraspid specimen (178) exhibits three rather faint lateral glabellar furrows. Another (169) shows a pygidium and thorax exhibiting strong trilobation, with the pygidium containing six distinct ring furrows and six distinct corresponding interpleural furrows. About three sets of less distinct furrows are also present. Specimen 169 exhibits an adult-type pygidium but has only nine thoracic segments.

Comparison to Related Species

This species is very closely related to Homalonotus (Dipleura) dekayi Green. It differs in the following respects:

1. Presence of one deep marked ring furrow in anterior part of pygidium (present in 95 of 95 pygidia collected). H. dekayi specimens from the Hamilton foundation of New York State lack this feature once the pygidium has taken on mature characteristics. Clarke (1, p. 11) notes that "the axis and pleurae (of H. dekayi) of the pygidium are never strongly ribbed even at an early stage of growth, and at maturity the annulations are represented only by low obsolescent ridges or by rows of punctae."

2. Outline of posterior margin of cephalon. The margin is curved anteriorly between that part of the margin closest to the eye and the genal angle, and the genal angle is not well defined. The genal angle of H. dekayi is better defined and this margin curves to the rear. However, breaking and tilting of the cephalon may cause this posterior margin to take on a slightly different shape and neither this species nor H. dekayi has a posterior margin of the cephalon differing greatly from a straight line in shape.

3. Ontogeny. Cooper (4, p. 3) has pictured specimens of H. dekayi with thoraxes 5.5, 6.7 and 7.2 mm. in length. The first exhibits four glabellar furrows and all three have thirteen thoracic segments. Specimens of the homalonotid found at Accra with thoraxes

3.2, 5.4 and 6.9 mm.[2] long have six, seven and nine thoracic segments and only the first exhibits glabellar furrows (at least three are present). See graph #1.

4. Overall size. Cooper states that "adult Dipleura dekayi" is a large trilobite averaging about 6 inches in length but attaining 9 inches in individual examples (4, p. 4). Specimens viewed by the author at the United States National Museum, the Museum of Comparative Zoology at Harvard and the Peabody Museum at Yale bear this out. The species found at Accra, however, averages about two and a half to three inches in length and one specimen (number 127), considerably larger than any other, has a length calculated to be 4.8 $\pm$ 0.2 inches (approximately 122 mm.). The calculation of total length was made using the constants obtained on graphs # 2, 4, 5, 8. The calculation of probable error was made using the method above on the complete specimen, number 129, and then comparing the calculated value of 86.1 mm. to the measured value of 80.8 mm. The size attained by an arthropod, however, is probably greatly a function of the quantity of nutrients available to it.

5. Rostral plate. The rostral plate of the Accraian species exhibits a protrusion not found in H. dekayi or in any other species of Dipleura, but exhibited by Burmeisteria (Digonus) gigas. However,

2. Numbers 178, 177 and 169.

the pygidium of Burmeisteria is much narrower and trilobate than that of the Accraian species and the glabella is furrowed in the adult. The rostral plate appears to be somewhat narrower anteriorly in H. (Dipleura) dekayi than in the Accraian species.

6. Hypostome. The hypostome of the Accraian species has smaller anterior wings and is less indented in the anterior margin than is the hypostome of H. dekayi (16, plate XLIII).

Clarke estimates that the original fragment of H. oiara "indicates a cephalon having approximately a length of 27 mm. and a width across the base of 34 mm." (1, p. 6). See graph #2. If Clarke's estimates can be accepted H. oiara does not have a cephalon shaped like the cephalon of the Accraian species. The ratio, width of cephalon / length of cephalon, is 1.9 for the Accraian species and also for H. dekayi. Kozlowski, on the other hand, writes that H. oiara differs from H. dekayi only in that the lateral side of the glabella is more concave (14, p. 21).

H. clarkei Kozlowski (14, plate I) exhibits a pygidium with one marked ring furrow but this pygidium is more acuminate than is the Accraian species.

DATA AND GRAPHS

Abbreviations used:

L_c	=	length of cephalon
W_c	=	width of cephalon
L_{pyg}	=	length of pygidium
W_{pyg}	=	width of pygidium
W_{ga}	=	anterior width of glabella
W_{gp}	=	posterior width of glabella
L_g	=	length of glabella
E_r	=	distance from mid-point of eye lobe to back of cephalon
EE	=	distance between mid-points of eye lobes
N	=	degree, the number of thoracic segments
L_{th}	=	length of thorax
L_{tot}	=	total length of trilobite

C. calculated or extrapolated

Circled data are likely to have particularly high errors in measurement.

All measurements are in millimeters.

D A T A

Number	Locality	L_c	W_c	L_{pyg}	W_{pyg}	W_{ga}	W_{gp}	L_g	E_r	EE	N	L_{th}	L_{tot}
1	F14		45			14.5	20	19	11	27.5			
2	F14					9.5		12					
3	F14						10	11	6				
4	F14					14.5	20	18.5		29			
5	F14						14.5	14.5					
6	F14					10	13.5	12.5	8				
7	F14							11	7				
8	F14	20				12	16	14					
9	F14	12.5				7	9.5	8.5	5.5				
10	F14					14	21	18	11.5	28			
11	F14	18.5	31			11	14	13.5	8.5	20			
12	F14					7.5		10	7				
13	F14					11		12		24			
14	F14					7	9.5		6				
15	F14					8		10	6.2				
16	F14					13.5		15.5					
17	F14					11.5		13.5					

Number	Locality	L_c	W_c	L_{pyg}	W_{pyg}	W_{ga}	W_{gp}	L_g	E_r	EE	N	L_{th}	L_{tot}
18	F14					8	10.5	10					
19	F14					8.5	10.5	10.5		15			
20	F14					12	16	15					
21	F14	7.2				4.5	5.8	5.5	4.0	8.0			
22	F14							17	10.5				
23	F14					9.5	13	12					
24	F14					13	17	16.5	9.5	23.5			
25	F14	11.5				7	9	8.8		12.5			
26	F14						9		6				
27	F14	12.5				7.5	9.5	9	5.5	14			
28	F14	25				14.5		17.5					
29	F14	20.2	31.2			11.5	14	13.9	8.5	22			
30	F14	13				7.5	10	9.5	6.0	15.5			
31	F14	12.5					9		6.0	13			
32	F14						11	10.5	6.2				
33	F14	23.5				13.5		17		23			
34	F14	19							8.3				
35	F14	23						16	10.5				

Number	Locality	L_c	W_c	L_{pyg}	W_{pyg}	W_{ga}	W_{gp}	L_g	E_r	EE	N	L_{th}	L_{tot}
36	F14					6.6				14			
37	F14					10.7				20			
38	F14					8		9.8		15.5			
39	F14		23.5			8.0	10.4	10.0	5.8	15.5			
40	F14					8.4	10.5	10.1					
41	F14	13.6				8		9.5	6.2				
42	F14					9.6		10.9					
43	F14					7.5	9.9		6	14.8			
44	F14		23.6			8.0	10.3		5.5	15.6			
45	F14	24.6					19.7	18.0	11.5				
46	F14					9.9	12.9	12.3	7.3	18			
47	F14					16.8	22.2	20		31.9			
48	F14		30			8.3		10.8	6.8	16.2			
49	F14		42.2			13.7	16.4	16.4	9.4	25.5			
50	F14		43			14.0	17.0	17.0	11.0	25.6			
51	F14					12.0			9.1		13	32	64
52	F14	18.2	29			11.2	14.9	13.0	8.1	20.1			
53	F14						8.9	8.8					

Number	Locality	L_c	W_c	L_{pyg}	W_{pyg}	W_{ga}	W_{gp}	L_g	E_r	EE	N	L_{th}	L_{tot}
54	F14	22.6	37.0			13.0	17.4	15.3	8.5	24			
55	F14		41					13.5					
56	F14					10.3		12.6	7.9	19.2			
57	F14						7.9		5.0	11			
58	F14	13	24.8			7.2	9.5	9.5	5.7	14.2			
59	F14	10						7.2	4.9	11.6			
60	F14					11.9				22			
61	F14	12.8					9.9	9.0	6.1	13.8			
62	F5										13	38.5	
63	F14			26	29.5					32	13	61	
64	F14	17.9	36.0	15.3		11.0	13.0	13.7	8.2	20	13	25.9	60.1
65	F14					8.3	11.6	9.4	6.9	13.9			
66	F14						9.7		5.6				
67	F14					13		16					
68	F14			8.9	9.3								
69	F14	13.0	21.2			7.5	9.2	8.9	5.7	13.5			
70	F14	28.6	51										
71	F14		44.4				15.1		9.5				

Number	Locality	L_c	W_c	L_{pyg}	W_{pyg}	W_{ga}	W_{gp}	L_g	E_r	EE	N	L_{th}	L_{tot}
72	F14	22.9				13		16.5	9.8				
73	F14	17.9				10.2		12.5	8.1	20	13		
74	F14					17.6	22.9	21.2	13.1	33.7			
75	F14					13.8	19.9	17.0	10	26			
76	F14	20.1				12.8	15.9	15.5	9.6	24.5			
77	F14					9.6	12.8	12.0	8.0	18.8			
78	F14						10.2			16.6			
79	F14	16.9				10.4		12.9	7.8	17.6			
80	F14	14.0				7.3		9.8					
81	F14		15.4						3.5				
82	F14	16.8				9.9		11.8	8.4	18.1			
83	F8		17			5.0	6.3	6.4		9.1			
84	F14		40				17.7		9.0				
85	F14	15.5				9.1	12.3	11.0		18.0			
86	F14	18.9	35.0			10.0		12.9	7.8				
87	F5		36.3			13.1	16.3	15.3	9.2	24.2			
88	F4		24.8				10.8		6.1	15.5			

Number	Locality	L_c	W_c	L_{pyg}	W_{pyg}	W_{ga}	W_{gp}	L_g	E_r	EE	N	L_{th}	L_{tot}
89	F8	18.3				10.3	13.4	13.1	7.8	20.8			
90	F8					16.8		22.1					
91	F14						23.2	20.1					
92	F14				8.5	5.1	6.8	6.2	4.9	10.5			
93	F6			21.0	22.7						13	36.7	
94	F14					14.6				28.6			
95	F14			22	21.6	12.4	18.1	15.2		23.2			
96	F14				<u>21.8</u>						13	35.8	
97	F14				21.3		17.2		9.5		13	33.3	
98	F14			22.2	22.6								
99	F14			30.9	31.5								
100	F14			23.8	25								
101	F14			19.9	20.8								
102	F14			21.8	22.0								
103	F14			12.3	12.0								
104	F14							12.7	7.8		13		
105	F14								6.6		13		
106	F14							<u>11.1</u>	5.6		13		

Number	Locality	L_c	W_c	L_{pyg}	W_{pyg}	W_{ga}	W_{gp}	L_g	E_r	EE	N	L_{th}	L_{tot}
107	F14			17.2	17.9								
108	F14			25.3	26.7								
109	F4					9.7	12.0	11.6		17.0			
110	F14			23.0				13.2			13		71.9
111	F14							16.0	11.4		13	38.9	
112	F14	22.7						15.2	10.2				
113	F14	23	47.4			13.9	16.5	15.1	9.6	26	13	32.2	
114	F14					12.2	15.1	14.5	9.0				
115	F14					11.6	16.0	14.4					
116	F14	14.2				7.9		9.5	5.7	15.6			
117	F14	10.2				6.0	7.2	7.0	4.8	10.6			
118	F14					6.2	7.3	7.4					
119	F14	29		26.7	27.6								
120	F5			5.8					3.4		7+?		
121	F14			17.0	17.6			12.7			13		
122	F4		30.6			10.2	11.7	11.5	7.0	18.0			
123	F14		17.8			5.1				8.0			
124	F14	11.0	19.2			6.3	8.5	7.8	4.3	11.4			

Number	Locality	L_c	W_c	L_{pyg}	W_{pyg}	W_{ga}	W_{gp}	L_g	E_r	EE	N	L_{th}	L_{tot}
125	F14	8.7				5.8	6.1	6.3	4.0	10.3			
126	F14					11.2		13.9					
127	F14					20.9	27.8	25.7		40.1			122 c.
128	F14	25.8	55.4			14.9	20.3	19.2	11.4	29.0			
129	F14	22.0	41.8	23.5	25.2	14.5	19.2	16.0	9.8		13		80.8 c.
130	F5	29.0				15.8	19.2	19.2	12.6	31.6			
131	F14	26.8		27.2		17.2	21.5	19.5	11.9	31.8	13		
132	F14	30.3				16.5	21.1	20.1	13.6	32.9			
133	F14			16.9	18.0								
134	F14						19.1	18.6	10.9	27			
135	F14			10.6	13.2								
136	F14			28.8	31.2								
137	F14	13.3	26.4					10.2	6.8	16.1	13		
138	F14		34			11.1		12.9		19.9			
139	F6			22.7	23.7								
140	F12			23.3	24.1								
141A	F14	9.8				6.0	7.9	6.9			13		
141B	F14						13.3	12.9					

Number	Locality	L_c	W_c	L_{pyg}	W_{pyg}	W_{ga}	W_{gp}	L_g	E_r	EE	N	L_{th}	L_{tot}
142	F14			18.4	19.2								
143	F14			10.6	12.1								
144	F14			25.2	30.0								
145	F14	25.3	46			14.8	17.9	19.0	10.9	29			
146	F14		38.4					13.9	8.6	19.9			
147	F14					10.1		12.3					
148	F14		42.2				17.5		9.8	25.7	13	34	
149	F14			21.9	23.3								
150	F14	12.1	22.6	11.5		7.2	9.2	9.2	5.9	12.9	13	18.5	
151	F14		43.8						9.9				
152	F14						13.3	13.0	7.7		13		
153	F3					2.6					13 ?	13.7 c.	
154	F14					10.5	15.0	13.5					
155	F14	17.5				11.5	14.4	13.2	7.7				
156	F14	15.0	31.2			9.1	11.3	10.9	6.0	16.1			
157	F4	12.3				7.0	9.3	8.8		13.0			
158	F14					13.4		16.8					
159	F14	11.8	24			7.5	9.3	8.7	5.1	12.8			

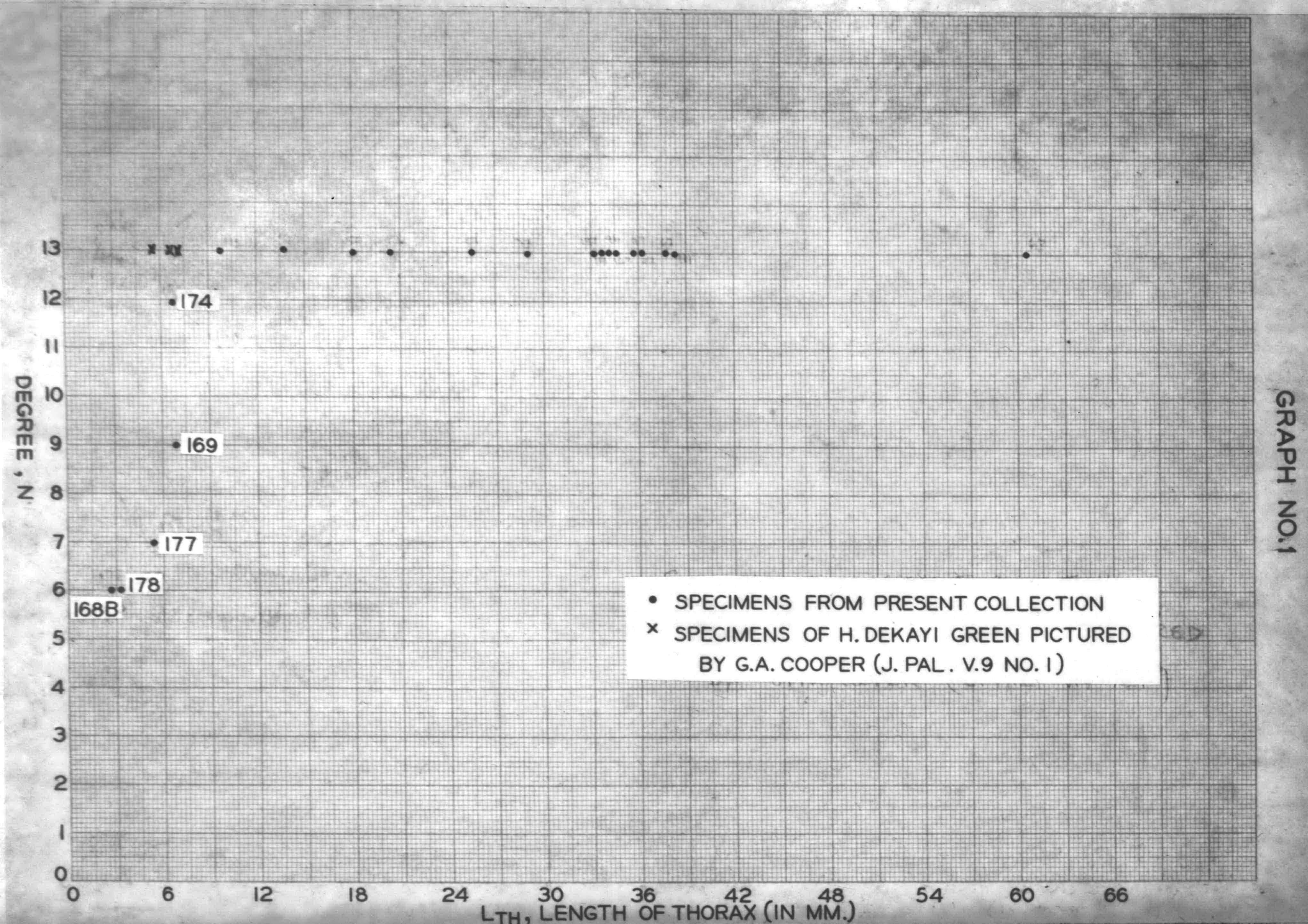
Number	Locality	L_c	W_c	L_{pyg}	W_{pyg}	W_{ga}	W_{gp}	L_g	E_r	EE	N	L_{th}	L_{tot}
160	F14	15	26.8			9.0		10.4	6.7				
161	F14			24.8	25.9								
162	F8	7.8					5.8	5.1	3.9	9.1			
163	F14			14.3	14.8	9.7	11.5	11.5	7.0	17.6	13		
164	F14	21.4				13.0		16.1		23.2	13	35	
165	F14	24.5	47			14.6	18.5	17.9	10.6	30.2			
166	F6		44.2			12.4	15.6	14.9	10.3	25.0			
167	F14	15.5				8.9	10.9	10.7	6.5	16.0			
168A	F14					7.5		9.4		15.1			
168B	F14			2.3	3.4						6	2.6	See Note 1
169	F14			5.6	6.5	4.5				7.5	9	6.9	See Note 2
170	F14	5.9	11			3.8	4.7	4.6	3.1	7.1			
171	F14			22.8	23.8								
172	F14	7.6				4.5		5.2					
173	F3	5.3	10.5	4.8	5.2	3.9	4.5	4.3	3.2	6.8	13	9.7	19.5
174	F6			3.1	4.6						12	7.7	
175	F14			20.5	21.1								

Number	Locality	L_c	W_c	L_{pyg}	W_{pyg}	W_{ga}	W_{gp}	L_g	E_r	EE	N	L_{th}	L_{tot}
176	F14		26.2		10.4	7.7	10.7	9.6		19.0	13	20.8	43.5
177	F14		8.8			3.1		3.6+		6.2	7	5.4	
178	F14		4.1?			1.9		2.1+			6	3.2	
179A	F14	12.5				7.4	9.0	9.0	5.5	13.9			See Note 3

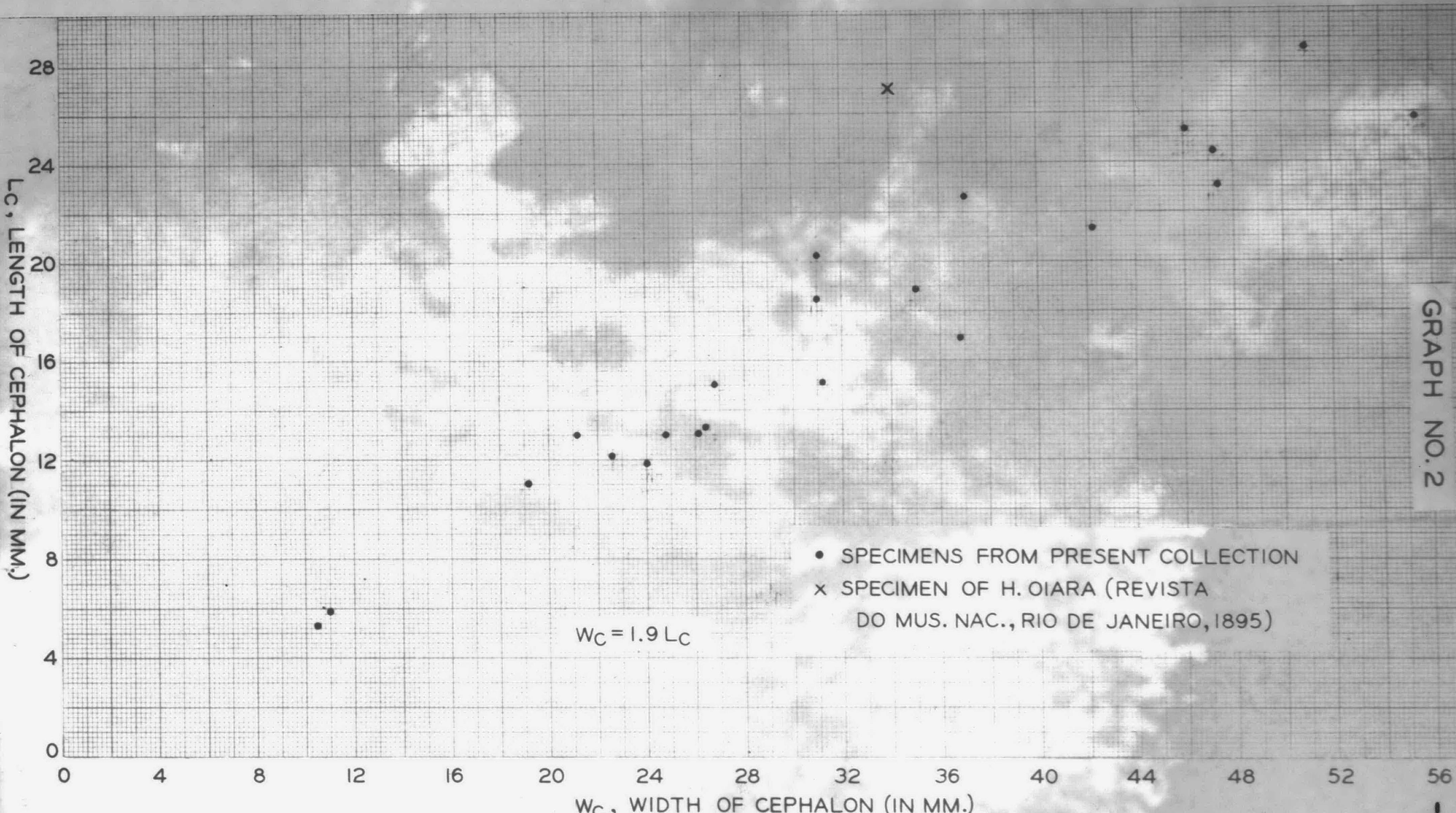
Note 1 Pygidium exhibits 6 distinct and 3 indistinct furrows on axis and in pleural areas.

Note 2 Pygidium exhibits two marked ring furrows.

Note 3 Specimen 179 contains a pelecypod + the trilobite.

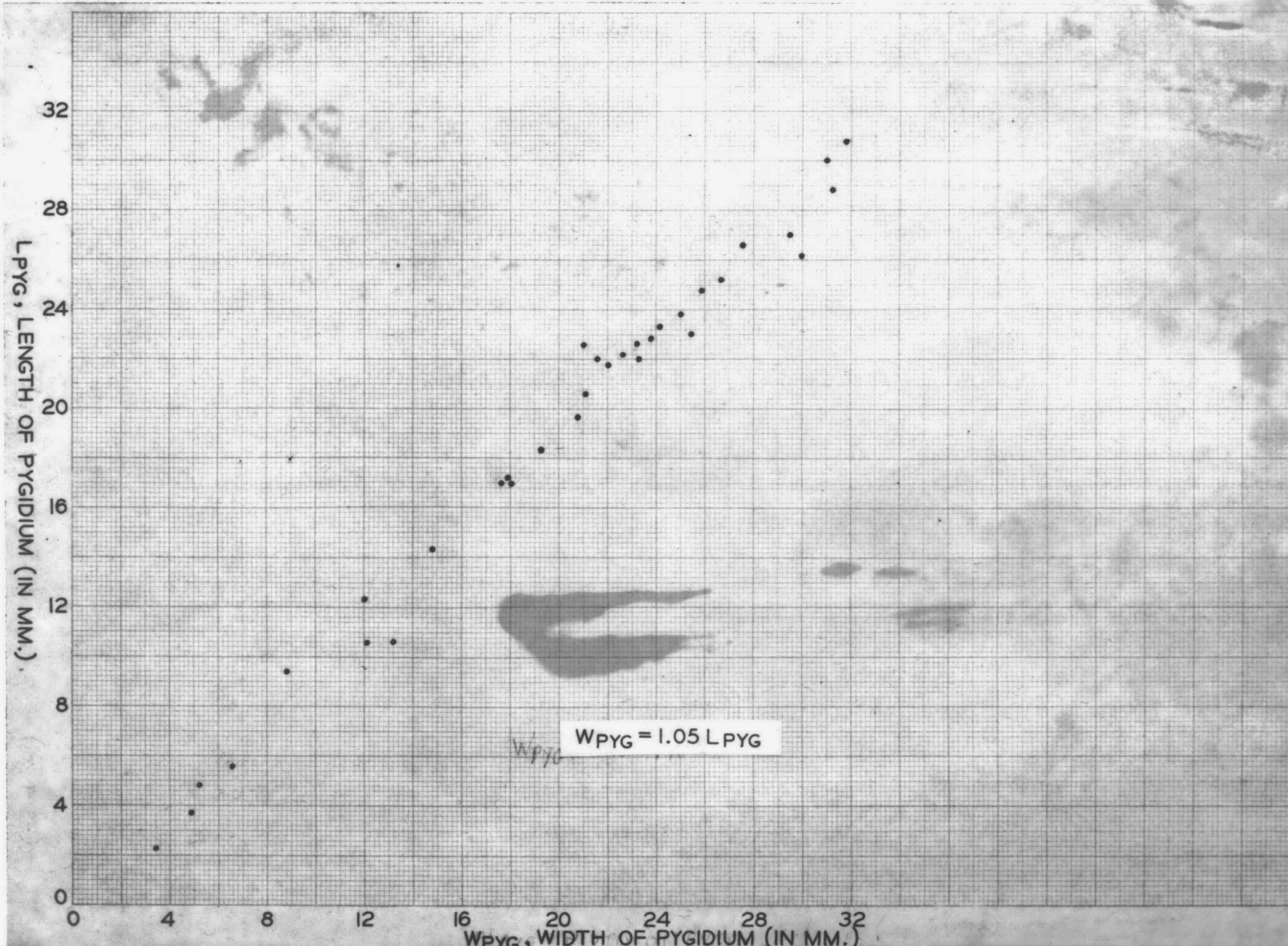

13
12
11
10
9
8
7
6
5
4
3
2
1
0
DEGREE, N
174
169
177
178
168B
0
6
12
18
24
30
36
42
48
54
60
66
L_{TH}, LENGTH OF THORAX (IN MM.)
• SPECIMENS FROM PRESENT COLLECTION
× SPECIMENS OF H. DEKAYI GREEN PICTURED BY G.A. COOPER (J. PAL. V.9 NO. 1)

GRAPH NO. 1



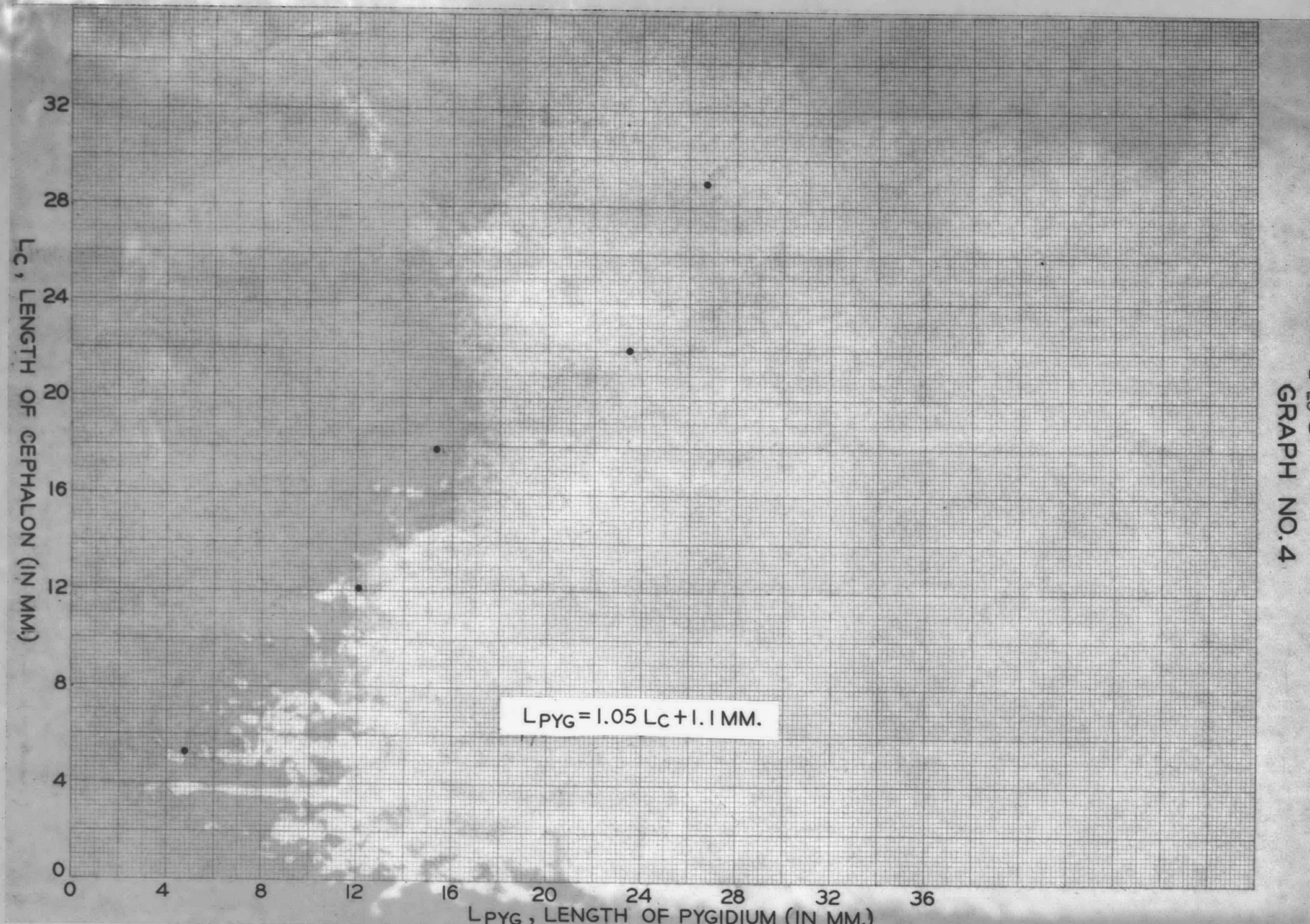
0
4
8
12
16
20
24
28
Lc, LENGTH OF CEPHALON (IN MM.)
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
Wc, WIDTH OF CEPHALON (IN MM.)
Wc = 1.9 Lc
• SPECIMENS FROM PRESENT COLLECTION
× SPECIMEN OF H. OIARA (REVISTA DO MUS. NAC., RIO DE JANEIRO, 1895)

GRAPH NO. 2

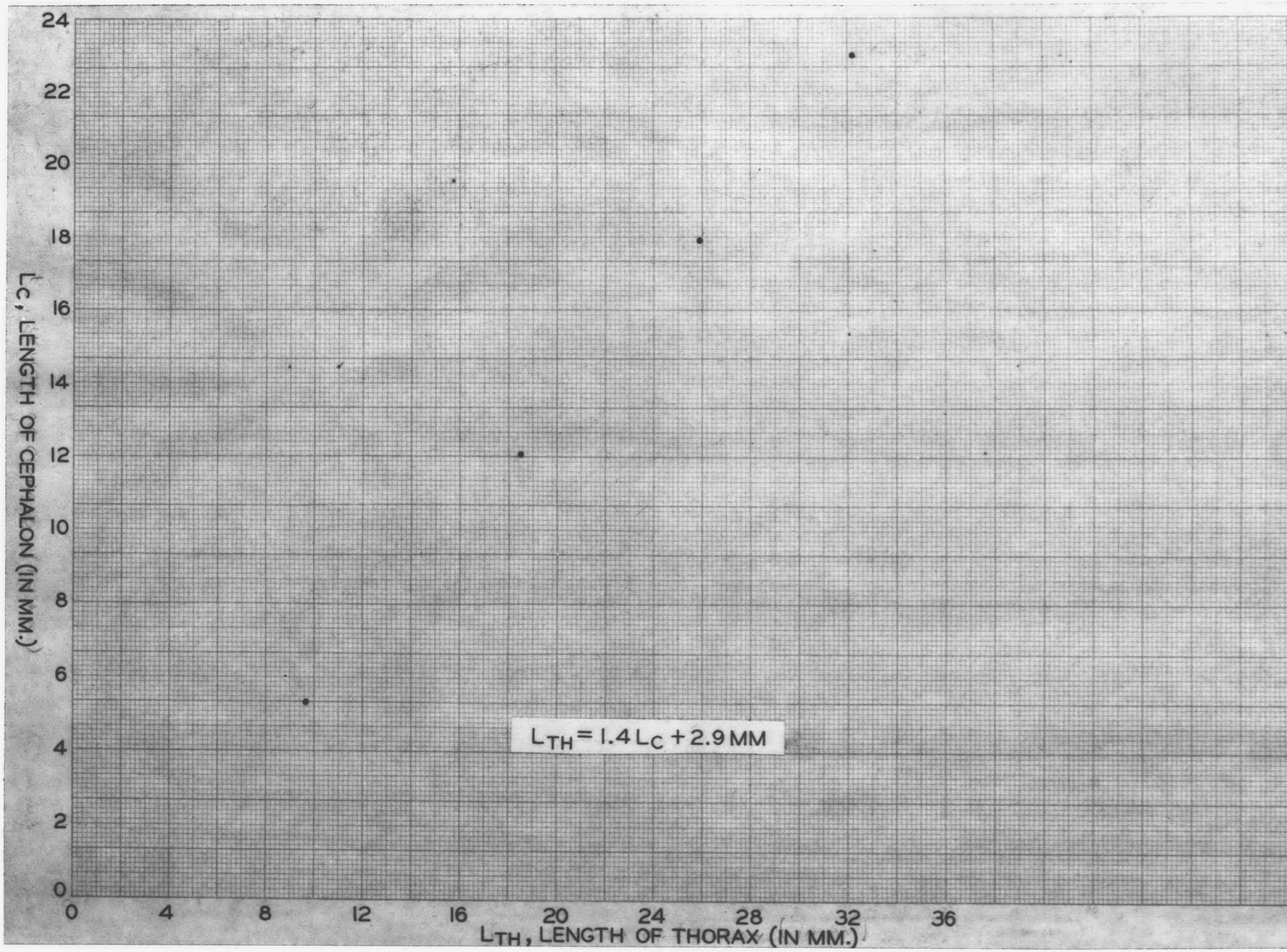

LPYG, LENGTH OF PYGIDIUM (IN MM.)
0
4
8
12
16
20
24
28
32
WPYG, WIDTH OF PYGIDIUM (IN MM.)
0
4
8
12
16
20
24
28
32
WPYG = 1.05 LPYG
Wpyg

GRAPH NO. 3

GRAPH NO. 4



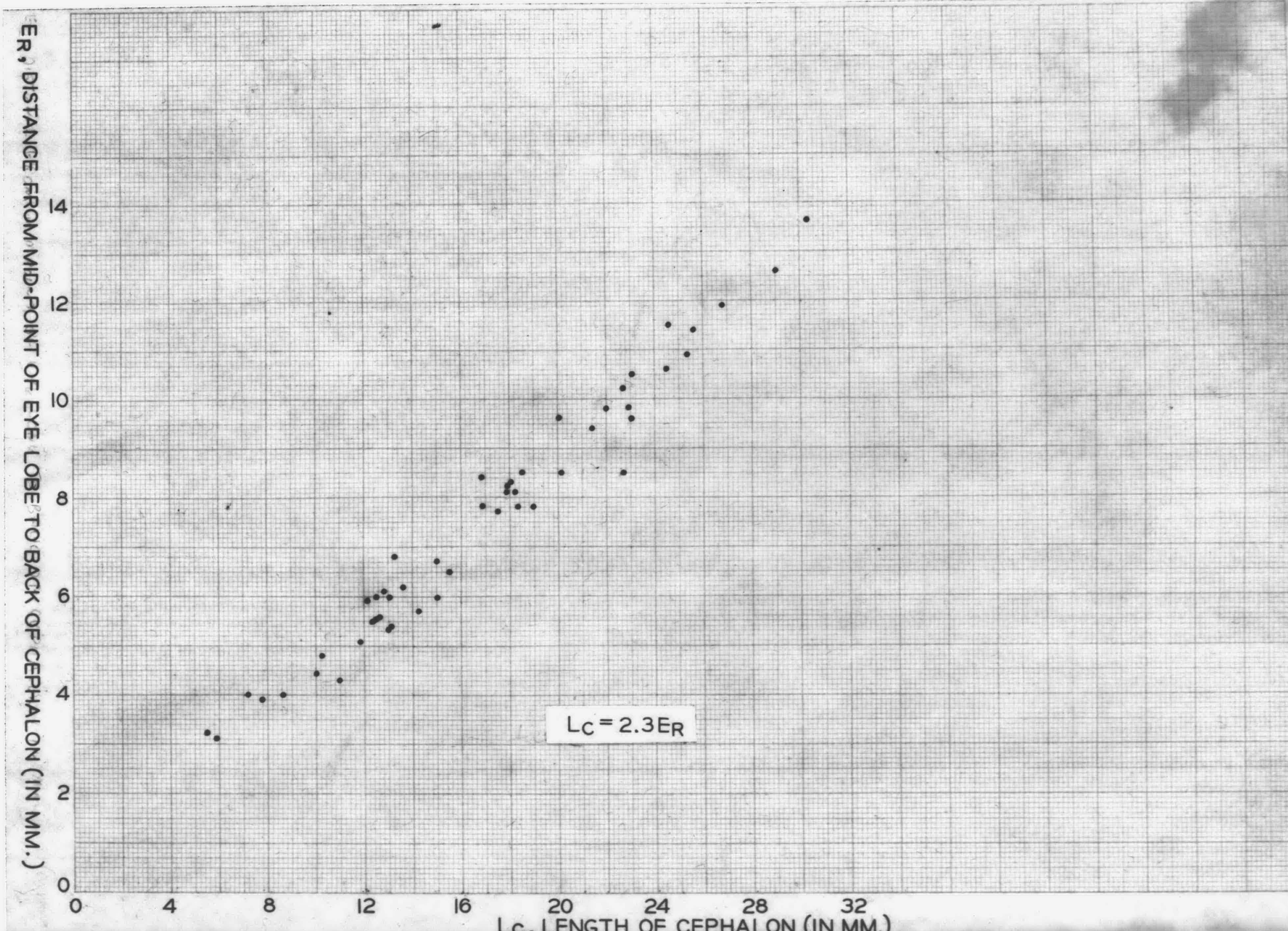
$L_{PYG} = 1.05\,L_C + 1.1$ MM.
L_C, LENGTH OF CEPHALON (IN MM.)
L_{PYG}, LENGTH OF PYGIDIUM (IN MM.)
0
4
8
12
16
20
24
28
32
36



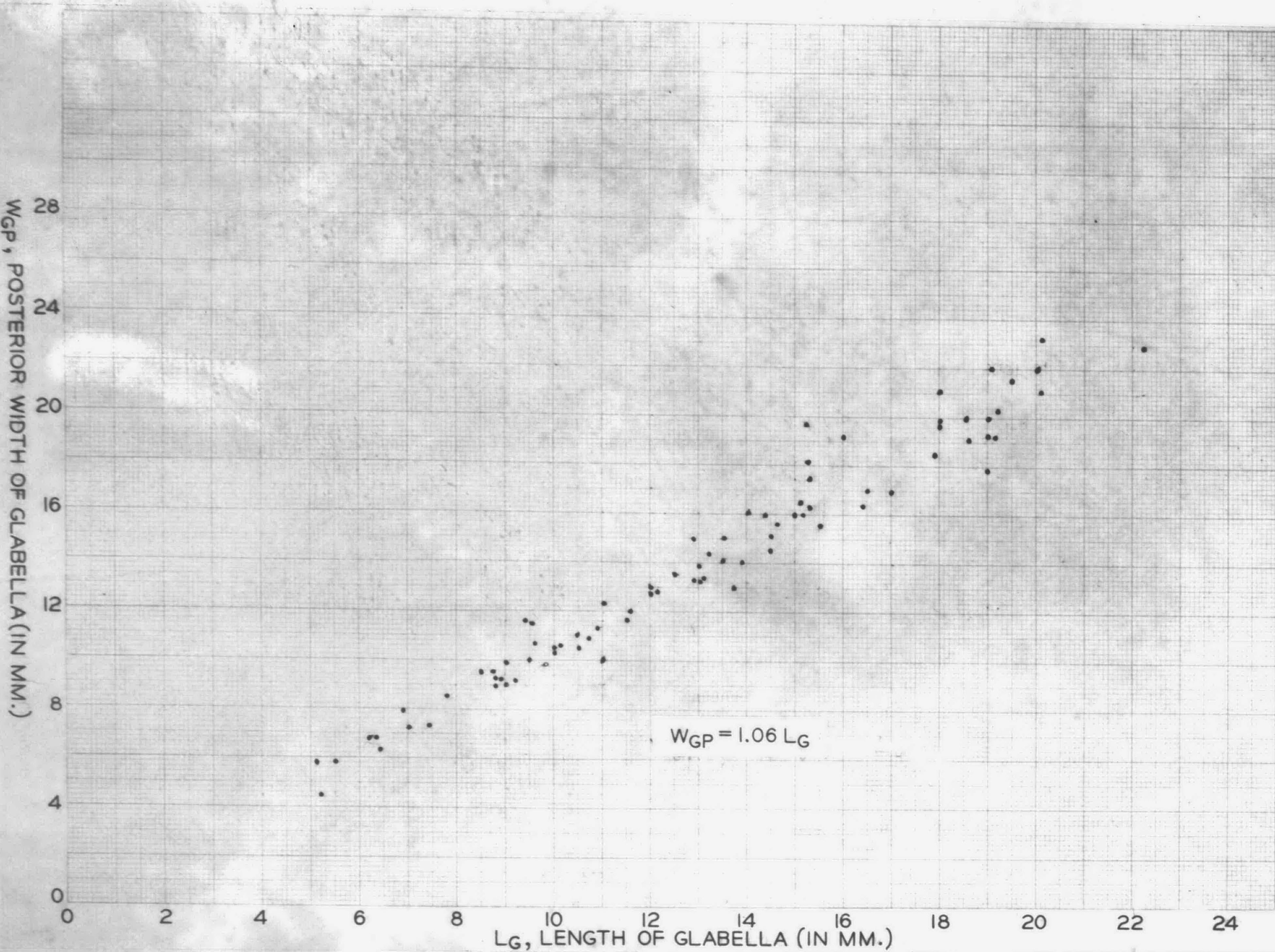
L_C, LENGTH OF CEPHALON (IN MM.)
24
22
20
18
16
14
12
10
8
6
4
2
0
$L_{TH} = 1.4 L_C + 2.9$ MM
0
4
8
12
16
20
24
28
32
36
L_{TH}, LENGTH OF THORAX (IN MM.)

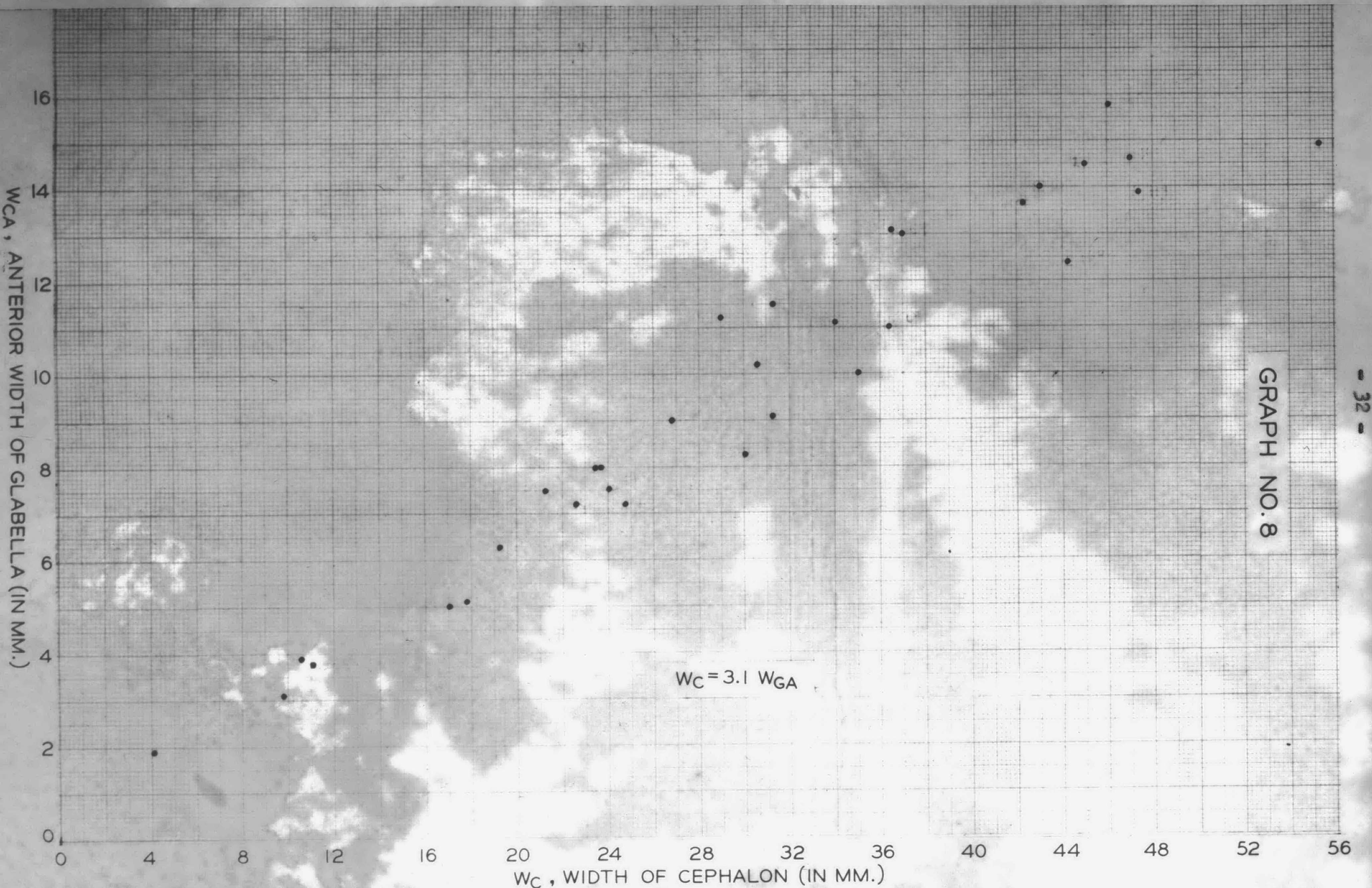
GRAPH NO.5

GRAPH NO.6

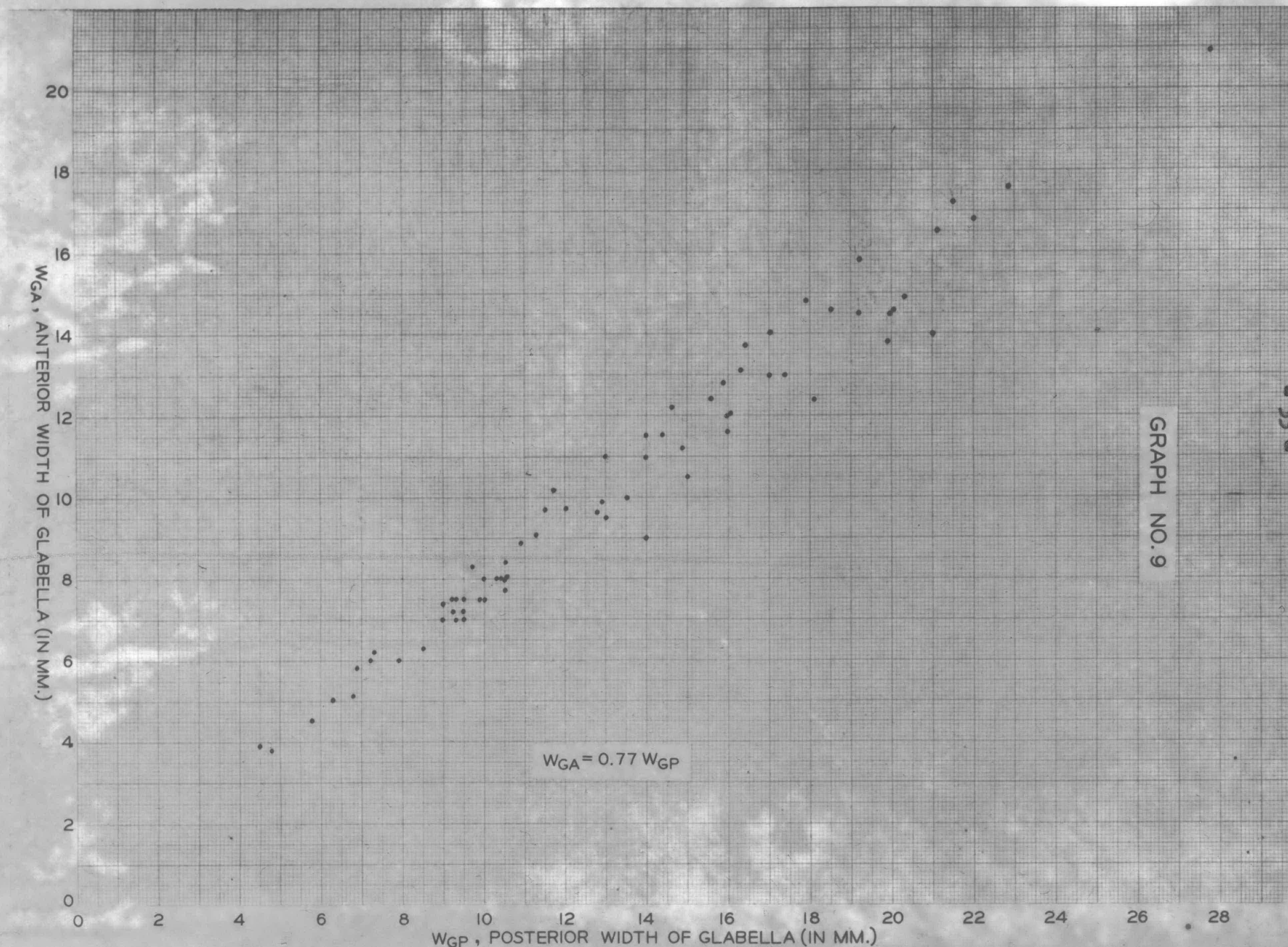

E_R, DISTANCE FROM MID-POINT OF EYE LOBE TO BACK OF CEPHALON (IN MM.)
0
2
4
6
8
10
12
14
0
4
8
12
16
20
24
28
32
$L_C = 2.3E_R$
L_C, LENGTH OF CEPHALON (IN MM.)

GRAPH NO. 7


W_{GP}, POSTERIOR WIDTH OF GLABELLA (IN MM.)
L_G, LENGTH OF GLABELLA (IN MM.)
$W_{GP} = 1.06\ L_G$
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28

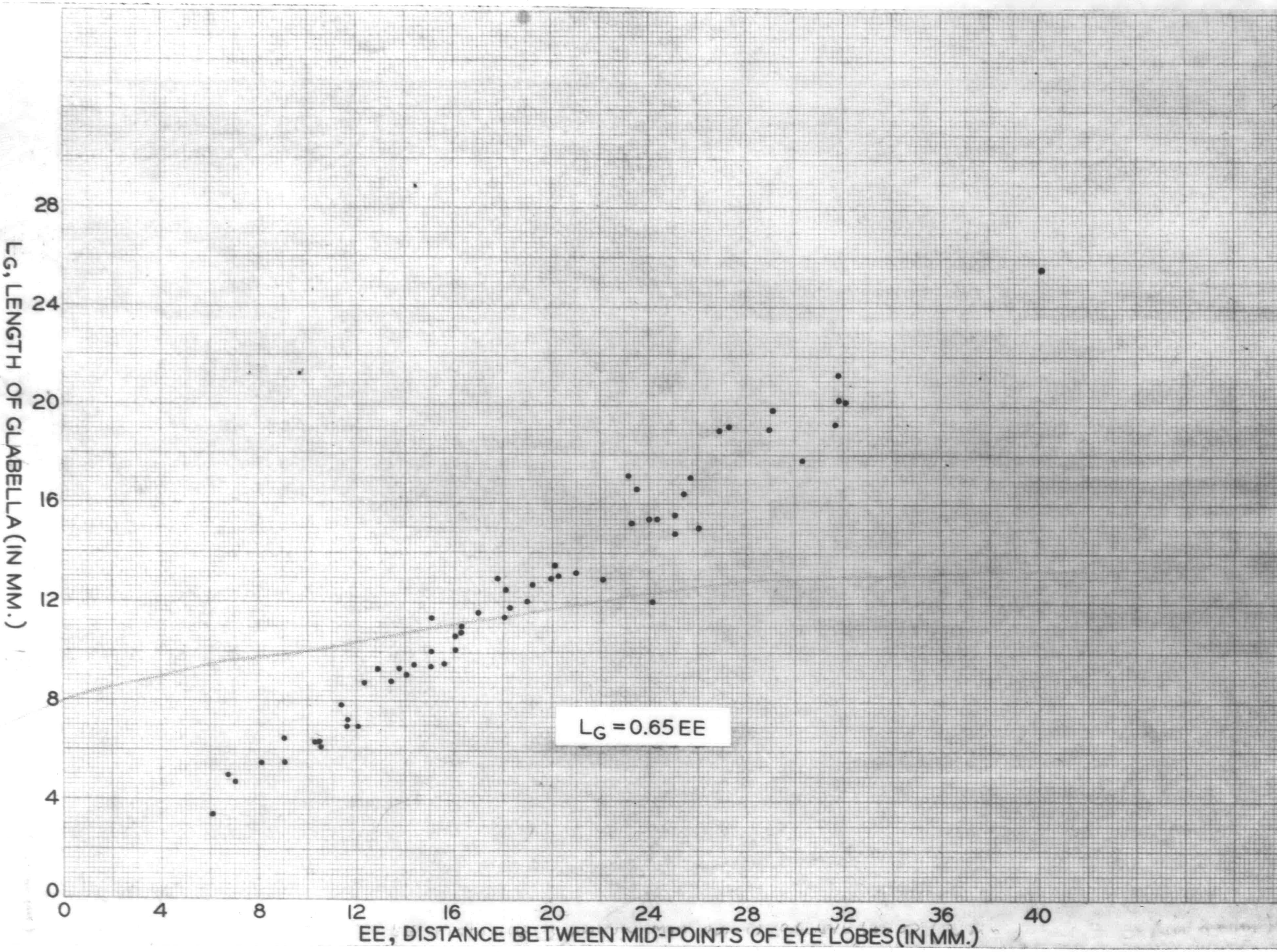

W_{CA}, ANTERIOR WIDTH OF GLABELLA (IN MM.)
0
2
4
6
8
10
12
14
16
$W_C = 3.1\ W_{GA}$
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
W_C, WIDTH OF CEPHALON (IN MM.)

GRAPH NO. 8



W_{GA} , ANTERIOR WIDTH OF GLABELLA (IN MM.)
W_{GP} , POSTERIOR WIDTH OF GLABELLA (IN MM.)
$W_{GA} = 0.77\, W_{GP}$
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28

GRAPH NO. 9


$L_G = 0.65$ EE
L_G, LENGTH OF GLABELLA (IN MM.)
EE, DISTANCE BETWEEN MID-POINTS OF EYE LOBES (IN MM.)
0
4
8
12
16
20
24
28
32
36
40

GRAPH NO. 10

BRACHIOPODA

TEREBRATULACEA [3]

In over thirteen hundred fossils collected by Saul at Accra only two articulate brachiopods were recovered. Both of these specimens are small terebratuloids, presumably members of the same species. The largest specimen, which is about seven mm. wide, is the impression of the interior of a pedicle valve. This pedicle valve has short, simple dental lamellae bounding a poorly impressed muscle field. The impress of low, rounded costae is prominent peripherally. The costae are separated from each other by low, rounded interspaces. The impressions of the punctae appear as minute pustules on the specimen. The anterior margin is largely broken off but a sulcus does not appear to have been present. The curvature of the beak is difficult to determine but appears to be suberect. The shell is subcircular in outline and appears to have had terebratulid cardinal margins.

The second specimen, which has a length of about two mm., consists of the internal and external impressions of a complete specimen. The pedicle valve is more highly convex than the somewhat smaller brachial valve. The brachial valve is circular in outline and bears no trace of a fold. Both valves are ornamented peripherally by low, rounded costae

[3] This section is written by Dr. A. J. Boucot.

but the umbones are smooth. Several prominent growth lines are present and the impressions of the punctae are evident. The impression of the interior is, unfortunately, not well preserved, and reveals very little in a positive way about the morphology of the specimen. However, it can be seen that the brachial valve lacks prominent median septum, as does the pedicle valve, and the dental lamellae must have been very short.

Ascertaining the generic and specific identity of these two terebratuloids is not possible owing to our ignorance of the cardinalia of the brachial valve. Ribbed terebratuloids have been previously reported in strata as old as the Gedinnian and its stratigraphic equivalents elsewhere.

<u>Discinisca</u> sp. [4]

One small specimen of this discinoid was collected. It is pictured.

<u>Lingula</u> sp.

Several specimens of a species of lingula were also collected. They too are pictured.

4. Identification was made by Dr. A. J. Boucot.

PELECYPODA

Seven genera of pelecypods were identified from the Accraian Series.[5] In addition to these, Davies (11) had identified Palaeoneilo, Glyptodesma, Lunulicardium and Conocardium. The possibility that specimens in the present collection might be identified as Palaeoneilo or Glyptodesma is discussed below. Conocardium is found almost exclusively in limestones, and it would be very unusual to find it in a sedimentary sequence with the lithology of the Accraian Series.[6]

One new species of the apparently austral genus, Pleurodapis, has been described.

Identifications made by the author were made using Shimer and Shrock (26), Clarke (1) (2) (3), and Hall (7) (8).

Leiopteria sp.

Several specimens of Leiopteria were collected and two were complete enough to identify positively. Leiopteria has a stratigraphic range from Silurian to Mississippian (26, p. 383).

5. Sphenotus and Ptychodesma were identified by Dr. McAlester who concurred with the author on the identification of the other pelecypoda found in the Accraian Series.

6. This information was obtained from Dr. McAlester.

Leptodesma? sp.

One specimen which is not well preserved is identified tentatively as *Leptodesma*. The two *Leiopteria* specimens vary considerably in the length-to-width ratio and it is quite possible that, were more collected, the "*Leptodesma*" would be found to fall in the range of variation of *Leiopteria*. A similar argument might be valid for the *Glyptodesma* identified by Davies (11). In this collection no *Glyptodesma* were found. Specimens of *Leptodesma* are recorded found in strata from Silurian to Mississippian in age (26, p. 385).

Ptychodesma sp.

Six identifiable specimens of this genus were recognized. This genus is found in the Hamilton and Chemung formations of New York State (8, pp. 352-355).

Nuculana sp.

About fifty specimens of *Nuculana* were collected and several are pictured to indicate their considerable range of size and shape. *Nuculana* has a worldwide distribution from Silurian to Recent times (26, p. 377).

Nuculites sp.

Nuculites is by far the most common pelecypod in the Accraian Series. It exhibits a great range of both biological and preservational variation. The size, shape, position of the umbo, and ornamentation of the shell vary greatly and, given specimens exhibiting the extremes of variation, one might well decide that several species were present. Specimens exhibiting features between the several extremes are present and this necessitates that the group be classified as one species. The author is very grateful to Prof. A. L. McAlester who pointed this out to him.

There is no one feature common to all the specimens assigned to this species.

The mode of preservation is such that the internal and external casts have been pressed together and the original shell usually completely dissolved out from between the two. The surface of the fossil, concave or convex, then exhibits features of both the internal and external of the shell; often one is more prominent than the other. Other pelecypods in this collection, notably Nuculana, have been preserved in the same fashion. This mode of preservation in Nuculites is made striking by the prominent, almost vertical, abutment on the internal side of the shell. Specimens of Nuculites in this collection exhibit the abutment prominently, faintly and not at all. Specimens which exhibit the abutment but do not exhibit any ornamentation greatly resemble Nuculites pictured by Clarke (3, plate 10) and Kozlowski (13, plate 3) from Paraná (Brazil). They do not, however, appear to be closely related to the Bokkeveld Nuculites pictured by Reed (20, plate 31).

Palaeoneilo, a genus identified by Davies (11) from the Accraian Series, is a round, taxodont shell with a characteristic notch in the posterior-ventral margin. A round specimen of *Nuculites* which exhibited such a notch but did not exhibit the interior abutment might readily be mistaken for *Palaeoneilo*.

Nuculites are found in beds of Ordovician to Devonian age (26, p. 377).

Sphenotus sp.

Four specimens of *Sphenotus*, a pelecypod found throughout the Devonian and into the Mississippian (26, p. 414) were collected.

Pleurodapis n. sp.

Eight specimens of a rather small shell, typically 20 mm. in length and 13 mm. in height, were collected. They belong to the same genus as *Pleurodapis multicincta* Clarke (1913), (3, pp. 185-187, plate 14).

This shell is equivalve, inequilateral and somewhat elongate and rather compressed in shape. The hinge line is straight and appears to extend the length of the shell; the low sub-anterior beak does not protrude beyond the hinge line and two small teeth visible on one specimen show the genus to be taxodont.

From the anterior part of the umbo there extends a prominent straight ridge, rounded in cross section, which forms a 35° angle with the hinge line and intersects the anterior margin to form a small marginal notch. That portion of the shell anterior to this ridge is mostly or wholly missing in all eight specimens. From the posterior part of the umbo to the posterior margin run four grooves interspaced by three ridges. The first groove forms an angle of about 25° with the hinge line. The first and second grooves are slightly curved convexly toward the ventral portion of the shell, are broad, and, in cross section, are gently rounded. The second ridge is less curved, is quite narrow and, in cross section, looks like an inverted letter V. The third and fourth grooves are flat bottomed depressions and are separated by a faint straight third ridge close to and parallel to the hinge line. This third ridge is fainter near the margin whereas all the other ridges and grooves on the shell become stronger near the margin. The hinge line lies in the fourth depression.

The posterior margin of the shell is highly sinuated by the ridging. There is a deep U-shaped indentation at the marginal emergence of the first ridge and the second groove; at the second ridge there is a sharp extension of the margin; the dorsal-posterior portion of the margin is then indented at the third and fourth depression and the third ridge. The shell is ornamented by numerous fine concentric growth marks which bend outwards atop the V-shaped second ridge. Numerous fine closely spaced radial lines are present atop the first posterior ridge. Some specimens exhibit the ridges and grooves much more distinctly than others.

The closed shell most probably gapes in the vicinity of the first posterior ridge and possibly also at the second.

The interior of the shell is unknown.

This species differs from P. multicincta in that:

1) The hinge line and probably the teeth extend for a greater distance along the dorsal margin.

2) The number of ridges and grooves appears to be fixed.

3) The posterior margin is very complex; in P. multicincta the posterior margin curves smoothly and is simply notched at the emergence of ridges.

4) The first and second ridges differ as described above; in P. multicincta both of these ridges are much like the second ridge of this species.

5) The anterior ridge forms an angle of 35° with the hinge line. This angle is about 50° in Clarke's figures (13, plate 14).

6) The growth lines are less distinct in this species.

7) The specimens of this species are smaller than Clarke's specimens.

8) The hinge line is straighter in this species.

Clarke writes that "Pleurodapis may perhaps with propriety be regarded as an austral precursor of the genus Pleurophorus." (13, p. 187). This seems unlikely because Pleurophorus is a dysodont pelecypod but perhaps Pleurodapis multicincta and the West African species only resemble each other in their external characteristics. Clarke also states that "The species . . . is in close association with Homalonotus, Leptocoelia and other characteristic members of the Devonian fauna." (13, p. 187).

GASTROPODA

The following gastropods from the Accraian have been identified by Dr. A. J. Boucot in consultation with Dr. Ellis Yochelson. Specimens of each genus are pictured.

Bucanella? n. sp.

It is stated in Shimer and Shrock (p. 441) that this genus is found in strata of Ordovician to Pennsylvanian age.

Ptomatis cf. moreirai Clarke

This same source (p. 441) states that this genus is found in rocks of Devonian age.

Liospira? sp.

One crushed gastropod was tentatively identified as Liospira, a genus which Shimer and Shrock state is found only in Ordovician rocks (p. 451). This might be the fossil identified by Davies as Pleurotomaria?.

Tropidodiscus sp.

This gastropod is found in rocks of Ordovician to Devonian age (26, p. 443).

Loxonema sp.

The species of *Loxonema* found in the Accraian series is a very low spired form. The genus is found in rocks of Ordovician to Mississippian age (26, p. 461).

HYOLITHIDS

Hyolithids are known in strata of Cambrian to Permian age (26, p. 525).

Hyolithes cf. *aclis* Hall

Several specimens on which not much detail was visible were collected. One which is not pictured in this paper exhibits an elevated median portion separated from the lateral longitudinal area by low depressions. Very faint irregularly spaced concentric markings are present at the widest part of the shell. The complete shell would measure about 20 mm. in length. The apical angle is 22° to 23°. This is probably the fossil identified by Davies (11) as *H. actis* Hall. The author can find no record of an *H.* "*actis*". *H. aclis* is found in the Hamilton Series of New York State (5, p. 197).

Hyolithes sp. A.

One specimen, the hyolithid in the best condition, exhibits a longitudinal ridge indicating that the shell had a triangular or quadrangular cross section. This species might be the *H.* cf. *aclis* described above or perhaps *H. aclis* (var. *petaloidea*?). See (8), plate XXXII, fig. 30. The specimen is pictured.

Hyolithes sp. B

The one fairly well preserved specimen of this species exhibits no growth marks or striae and has an apical angle of 22°. The specimen is 20 mm. long. At 4.5 and 10.5 mm. from the acute extremity there are straight lines perpendicular to the axis of the shell. These appear to be internal abutments.

The wide extremity exhibits a curved margin which is less curved than a circular arc. In outline it resembles pictures of *H. aclis*.

This species might be the *H.* cf. *aclis* described above but it is certainly not *H. aclis* which is known not to have the abutments. This species is pictured.

Hyolithes sp. C

Two specimens of a second unpictured hyolithid were collected. This species exhibits an apical angle of 13° to 14° and, near the widest part, exhibits faint microscopic longitudinal striae and possibly fainter concentric growth lines. A ridge in one specimen may indicate that the species was three or even four sided. One specimen has a semicircular border outline at its wide extremity. Both specimens are 16 mm. in length.

TENTACULITIDS

Tentaculites are known in strata of Ordovician to Devonian age. They are extremely abundant in Silurian and Devonian strata (26, p. 526).

Tentaculites sp.

The form of the shell is elongate-conical and straight, with prominent rounded annulations, $2\frac{1}{2}$ to the mm. The ratio of annulation width to inter-annulation width is 4 to 7. The shell tapers very slightly, not to a point, but to an extremity that is sub-square in longitudinal section. The sub-square area has a side about equal in length to two annulations plus the distance between them, about 0.7 mm. Preservation of the one specimen in reasonable condition is not good enough to determine if the shell is striated.

The annulations, but not the tapering or extremity resemble *T. scalariformis* Hall (26, p. 526).

OTHER ORGANIC REMAINS

Other fossil remains were collected from the clay shale unit of the Accraian Series. These include: one small smooth ostracod and one ornate ostracod, both of which are to be studied, plant fragments, one of which is pictured, and some crustacean fragments.

In the lower sandstone unit two types of fossils were found. These are a poorly preserved, featureless algal growth and a branching rope-like fossil remain resembling Arthrophycus. The rope-like fossil is about 12 mm. in diameter with distinct or indistinct annulations, about five to the centimeter. This fossil is pictured.

SPONGES

Robert M. Finks, Department of Geology,
Brooklyn College, Brooklyn, New York

Introduction.

The sponges are preserved as impressions of a coherent skeletal net upon bedding surfaces of a soft clay. The spicules themselves have been lost, although the impressions are emphasized in some cases by a light limonitic stain. None of the specimens is complete, but the portions preserved are undisturbed except for being flattened on the bedding plane. Since the tiny individual spicules of these sponges were held together in life only by the flesh of the sponge, the fact that they have maintained their strictly parallel orientation in the fossils implies relatively quick burial or else quiet water conditions between the time of their death and their entombment in the mud. It is likely that they were quickly buried.

Otherwise large benthonic scavengers, such as the trilobite preserved next to one of the sponges, would almost certainly have disrupted them. Repeated influxes of mud to the sea floor is suggested by sponges separated vertically by no more than one millimeter of clay. (Locality F4.)

Seven of the eight specimens in the collection are of the simple hexactinellid sponge Prismodictya Hall and Clarke. The other is a coarser-meshed sponge belonging to the same family but too fragmentary to determine further.

The Prismodictya specimens are noteworthy for being the earliest known representatives of the genus, as well as the first described from outside North America. Until now, this genus has not been reported from beds lower than the Naples group (upper Devonian) of New York. It ranges upward from there into the Osagian (middle Mississippian). Its occurrence here in the lower Devonian[7.] is not surprising, however, for it is a simple type with ancestral forms known from as far back as the Ordovician (Acanthodictya Dawson and Hinde, 1889) and descendant forms from the Permian (author, in press).

7. Dr. Finks had been informed by the author that the Accraian Series was possibly Lower Devonian. See "Conclusions" below for discussion of the age of the Accraian sequence.

SYSTEMATIC PALEONTOLOGY

Phylum Porifera, Grant, 1872.

Class Hexactinellida Schmidt, 1870.

Order Lyssacina Zittel, 1877.

Family Dictyospongiidae Hall, 1882.

GENUS PRISMODICTYA Hall and Clarke, 1899.

Hall, J. and J. M. Clarke, 1899, p. 79.

Prismodictya sp.

DESCRIPTION: Sponge prismatic, probably with eight sides; parallel-sided for most of its length but strongly contracted at both apertural and basal ends; length of sponge well in excess of 48 mm., width of faces constant at 6 - 7 mm. except near ends where they narrow to half this width or less; probable oscular opening as small as 6 mm. in diameter; wall very thin and probably one spicule-layer thick; skeletal mesh very fine, consisting of more or less uniform quadrules about 0.2 mm. in diameter; individual spicules difficult to delimit but probably stauracts of at least two size-orders in quincuncial alternation, with ray-lengths respectively equal to, and double, the quadrule width; close-set, parallel, probably monaxial prostalia, up to 2 mm. long, appear to bristle about the osculum and along the sides of the body; no root-tuft is preserved.

DISCUSSION: The fineness and uniformity of the skeletal mesh is the most distinctive feature of this sponge among the characters useful at the specific level. In nearly all described dictyosponges the finest quadrules are somewhat coarser than those of the present specimens, and much larger quadrules, outlined by spicule bundles, are commonly present in addition. Because of the incomplete nature of the present material, it is not possible to compare it fully with previously described species, nor is it desirable to base a new species on it. The closest described form would seem to be Prismodictya aulophia Hall and Clarke, 1899 (p. 88) from the Chemung of New York, which has a similarly fine net; its other distinctive features, namely, a set of larger secondary quadrules and the strong concavity of its prism faces, can not be found on the present specimens.

Dictyosponge, genus et species indeterminata

Several distorted fragments of a dictyosponge, with primary quadrules 1 mm. to 2 mm. in diameter, occur as patches on a bedding surface over an area at least 65 mm. wide. It almost certainly represents a dictyosponge but cannot be determined further. The distortion of these fragments suggests post-mortem disturbance of the sponge prior to its burial.

REFERENCE CITED

Hall, J. and J. M. Clarke, 1899, A memoir on the Paleozoic reticulate sponges constituting the family Dictyospongidae, New York State Museum Mem. 2, pp. 1-350. text figs. 1-45, pls. 1-70.

CONCLUSIONS

The fossil collection was not adequate to enable the author to pinpoint an age for the Accraian Series. The terebratuloids show that the series can not be older than Gedinnian and the homalonotids show that it can not be younger than Givetian. Other fossils found in the series are not well enough known to aid in the dating problem, though most of the genera represented are in eastern North America more commonly found in Middle Devonian strata.

Devonian strata containing the terebratuloids Trigeria aff. Guerangeri de Vern, Meganteris and Amphigenia have been reported from Guinea (32), a thousand miles west northwest of Accra[8.], and these fossils, states Dr. A. J. Boucot, indicate that the strata are of Emsian (uppermost Lower Devonian) age. A further study of the Guinean Devonian paleontology would be necessary to determine if the two areas were within one basin of sedimentation and if they could be correlated. The terebratuloids found at Accra are ribbed and could be Trigeria but

8. In Reference (32), page 11, it is stated that E. de Chételat collected Trigeria from some blocks of compact sandstone at the joining of the Musa and Mankou, near the village of Tiantian. Some twenty kilometers to the southeast, on the Fofokouré Cliff, impressions which may have been Meganteris and Amphigenia were found in a saccharoidal sandstone. Other place names mentioned in the brief note are: Sagalou Cliff, Sagalou, the basin of the middle Fatala and the basin of the Monga.

not Meganteris or Amphigenia. Both the Devonian of Guinea and the Bokkeveld Series are of Lower Devonian age and one could take this as evidence that the Accraian was a Lower Devonian series.

The tentative correlations of the Accraian Series with the Bokkeveld and Hamilton Series must be disregarded. With the doubtful exception of Nuculites, no species is found in both the Accraian and either of the other series. Specimens of the highly variable Nuculites are found in the Bokkeveld (20), the Hamilton (8), and the Devonian fossils of Paraná (Brazil) (3). The fauna of the Accraian can not be correlated with any other Devonian fauna that has been studied. Nothing in the faunal assemblage can be correlated with certainty at the specific level with any known fossils but the genera represented are well known in many Lower and Middle Devonian sequences. It might be argued that since almost all the genera reported can be found in the Hamilton fauna the tentative correlation should not be dropped. This would be incorrect because the Hamilton has been studied more thoroughly than the Brazilian, Bolivian or South African beds and these series contain nearly as many of the Accraian genera. In addition the faunal facies of the Hamilton and the Accraian Series are similar and this might cause one to form a correlation between the two even though they were of somewhat different ages.

The conclusion therefore is that the Accraian Series is of Lower to Middle Devonian age and should not be correlated with any strata of this age studied to date.

TABLE OF FAUNAL OCCURRENCES

Accraian fossils	Hamilton (5),(6), (7),(8)	Bokkeveld (1),(10), (22)	Brazil = Pará and Paraná (1),(13)	Bolivia (1),(14)	North Africa (27),(29)
Prismodictya	X		?		
Discinisca	X	?	X		
Lingula	X	X	X	X	X
terebratuloid	X	X	X	X	X
Leiopteria	X		X		X
Nuculana	X	X	X	X	
Nuculites	X	X	X	X	X
Pleurodapis			X		
Ptychodesma	X				
Sphenotus	X	X	X	X	
Loxonema	X	X		X	
Ptomatis	X		X		?
Tropidodiscus		X	Falkland Is. only		?
Hyolithes	X	X	X	X	
Tentaculites	X	X	X	?	X
homalonotid	X	X	X	X	X

Paleontological results of this study are the description of a new species of homalonotid, the description of a new species of Pleurodapis Clarke, and the extension of the stratigraphic range of Prismodictya down into the Lower or Middle Devonian.

BIBLIOGRAPHY

1. Clarke, J. M., Revista do Museu Nacional do Rio de Janeiro, Vol. 1, 1895; "As Trilobitas do Grez de Ereré e Maecurú, Estado do Pará, Brazil".

2. Clarke, J. M., The Paleozoic Faunas of Pará, Brazil, Author's English Edition, 1900, (Archivos do Museu Nacional do Rio de Janeiro, Volume 10, 1899).

3. Clarke, J. M., Monographias do Serviço Geologico e Mineralogico do Brasil, Vol. 1, Rio de Janeiro, 1913; "Fosseis Devonianos do Paraná".

4. Cooper, G. A., Journal of Paleontology, Vol. 9, No. 1, Jan. 1935; "Young Stages of the Devonian Trilobite Dipleura Dekayi Green", pp. 3-5, pl. 1.

5. Hall, J., Natural History of New York - Palaeontology, Vol. 5, Part 2, Text; Albany, 1879.

6. Hall, J., Natural History of New York - Palaeontology, Vol. 5, Part 2, Plates; Albany, 1879.

7. Hall, J., Natural History of New York, Vol. 5, Part 1, (Lamellibranchiata 1), Albany, 1884.

8. Hall, J., Natural History of New York, Vol. 5, Part 1, (Lamellibranchiata 2), Albany, 1885.

9. Junner, N. R. and Felton, W. J., Lexique Stratigraphique International, Vol. 4, Fasc. 3, 'Afrique Occidentale Anglaise', "Accraian System".

10. Kee, J. W., The Invertebrate Paleontology of the Devonian of South Africa (unpublished, manuscript in the possession of Prof. A. J. Boucot, Massachusetts Institute of Technology).

11. Kitson, A. E., XIIIème Congrès Géologique International, Fasc. II, pp. 945-947 (1922), "Devonian Rocks at Accra".

12. Kitson, A. E., Gold Coast Geological Survey, Bulletin No. 2, (1928), "Provisional Geologic Map of the Gold Coast and Western Togoland with Descriptive Notes".

13. Kozlowski, R., Annales de Paléontologie, Vol. 8, Fasc. 3-4, Paris, 1913; "Fossiles Dévoniens de l'État de Paraná (Brésil), pp. 1-20, pl. 1-3.

14. Kozlowski, R., Annales de Paléontologie, Vol. 12, Fasc. 1-2, Paris, 1923; "Faune Dévonienne de Bolivie", pp. 1-112, pl. 1-10.

15. Lake, P., Annals of the South African Museum, Vol. 4, Part 4, Capetown, 1904; "The Trilobites of the Bokkeveld Beds", pp. 201-220, pl. 24-28.

16. Maryland Geological Survey, Devonian Plates, Baltimore, 1913.

17. Moore, R. C., Editor, Treatise on Invertebrate Paleontology, Part (E), University of Kansas Press, 1955; "Archaeocyatha and Porifera".

18. Moore, R. C., Editor, Treatise on Invertebrate Paleontology, Part (O), University of Kansas Press, 1959; "Arthropoda 1 (Trilobitomorphs)".

19. Reed, F. R. C., Annals of the South African Museum, Vol. 4, Part 3, Capetown, 1903; "Brachiopoda from the Bokkeveld Beds", pp. 167-200, pl. 20-23.

20. Reed, F. R. C., Annals of the South African Museum, Vol. 4, Part 6, Capetown, 1904; "Mollusca from the Bokkeveld Beds", pp. 239-274, pl. 30-32.

21. Reed, F. R. C., Annals of the South African Museum, Vol, 4, Part 8, Capetown, 1908; "New Fossils from the Bokkeveld Beds", pp. 381-409, pl. 47-48.

22. Reed, F. R. C., Annals of the South African Museum, Vol. 22, Part 1, Capetown, 1925; "Revision of the Fauna of the Bokkeveld Beds", pp. 27-226, pl. 4-11.

23. Saul, J. M., The Accraian Series (unpublished S. B. thesis, 1960, Geology Department, Massachusetts Institute of Technology).

24. Schwartz, E. H. L., Records of the Albany Museum, Vol. 1, Part 6, Grahamstown, South Africa, 1906; "South African Palaeozoic Fossils", pp. 347-404, pl. 7-10.

25. Sdzuy, K., Senckenbergiana Lethaea, Band 38, No. 5/6, Frankfurt am Main, Dec. 28, 1957; "Bemerkung zur Familie Homalonotidae", pp. 275-290.

26. Shimer, H. W. and Shrock, R. R., Index Fossils of North America, (New York, 1944).

27. Termier, H., Études Géologiques sur le Maroc Central et le Moyen Atlas Septentrional, Tome 3; Notes et Mémoires No. 33, Rabat, 1936.

28. Whittington, H. B., Biological Reviews, Vol. 32, 1957; "The Ontogeny of Trilobites", pp. 421-469.

29. Ziegler, A., Animal Geography in the Silurian (Gothlandien) and Lower Devonian (Gedinnien-Eifelien) Periods in Northern Africa (unpublished, manuscript in the possession of Prof. A. J. Boucot, Massachusetts Institute of Technology).

MAPS

30. Carte Géologique Internationale de l'Afrique, 1:5,000,000 (Bureau d'Études Géologiques et Minières Coloniales) Paris, 1952.

31. Geological Map of the Gold Coast and Togoland under British Trusteeship, 1:1,000,000, (1955), Reprinted (1956) as Geological Map of Ghana, Survey of Ghana.

32. Carte Géologique de Reconnaissance a l'échelle du 500.000^{e}, Notice Explicative sur la Feuille Kindia-Ouest, (Gouvernement Général de l'Afrique Occidentale Française) Paris, 1946.

33. Land Survey Map of Ghana, Survey of Ghana, 1:1250, (Edition of January, 1952), Reference No. X227, Map No. 60/40M.

34. Geology of Accra Town, Gold Coast Geological Survey, 1:25,000, (1956), D. Mason, CG/343.

35. Air Survey Sheets of Accra, Survey of Ghana, 1:1250, (1954), Reference Nos. X2270/192, 193, 194, 204, 205, 206, 207, 215, 216, 224.